Bryn Group Ltd

Gelliargwellt Uchaf Farm
Gelligaer
Hengoed
CF82 8FY

Bioaerosol Monitoring Report

October 2018



Cardiff Metropolitan University | Prifysgol Metropolitan Caerdydd

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Summary

Bryn Group Ltd operates an Anaerobic Digester (AD) and open windrow composting facility near Gelligaer, processing food and green waste from local authority collections, civic amenity sites and commercial clients. The Centre for Health, Safety and Environment (CHSE) / Cardiff Metropolitan University have been requested to carry out a bioaerosol monitoring programme on behalf of Bryn Group Ltd. The principal aim of the investigation was to address the requirements of the Bryn Group Ltd Environmental Permit: (WP3995FY/V004). The monitoring programme was commenced in April 2008. This report relates to monitoring undertaken on Tuesday 09th October 2018.

On-site monitoring and laboratory analysis was carried out in accordance with the Association for Organics Recycling (AfOR) protocol, 'A standard protocol for the monitoring of bioaerosols at open composting facilities' (AfOR, 2009). A new Technical Guidance Note: M9, Environmental monitoring of bioaerosols at regulated facilities, is currently being introduced by Natural Resources Wales and will be used for future assessments, as instructed. The intention of the AfOR protocol is to provide guidance for monitoring bioaerosols at open composting facilities and requires that levels of total mesophilic bacteria and the fungi *Aspergillus fumigatus* be monitored. The protocol notes that at enclosed or in-vessel facilities, there may be an additional requirement to monitor gram-negative bacteria. The Environmental Permit for Bryn Group Ltd stipulates that monitoring should report concentrations of total mesophilic bacteria, the fungi *Aspergillus fumigatus*, and gram-negative bacteria. As a result, concentrations of total mesophilic bacteria, the fungi *Aspergillus fumigatus*, and gram-negative bacteria were enumerated and compared with the relevant appropriate levels for interpretation.

Natural Resources Wales (NRW) utilise the protocols and guidance on bioaerosols published and adopted by the Environment Agency. The analysis and report has therefore been prepared with reference to Environment Agency appropriate levels and guidance. References to policy and guidance from the Environment Agency within the text therefore also refer to NRW.

On the day of monitoring, windrows in the quarry were screened between 08.00 and 12.00. Shredding of material was undertaken in the AD reception throughout the monitoring period. Food waste was delivered to the AD reception area by refuse vehicles between 11.00 and 13.00. A full set of results and analysis can be found in Section 7.0, page 25. Appendix 5, page 44, provides a graphical summary of past monitoring results, up to and including the current monitoring exercise. The levels of total mesophilic bacteria, gram-negative bacteria and *Aspergillus fumigatus* measured at all locations were below the guidance values set by the Environment Agency of no greater than 1,000 colony forming units (cfu) per m^3 total bacteria, 300 cfu per m^3 gram-negative bacteria and 500 cfu per m^3 for *Aspergillus fumigatus*.

Concentrations of mesophilic bacteria (mean 447 cfu/m^3), Aspergillus fumigatus (mean 183 cfu/m^3) and gram negative bacteria (mean 6 cfu/m^3) at the location downwind of the AD facility were all below appropriate levels suggested by the Environment Agency/NRW, representing 45%, 37% and 2% of the guidance values, respectively. The sampling location downwind of the AD facility conformed to the requirements of the protocol closely during the mesophilic bacteria and gram-negative bacteria samples, being 3^o from directly downwind. The wind direction during the *Aspergillus fumigatus* sample meant that the sampling location was 26^o from being directly downwind but this is still within acceptable limits of the protocol.

Concentrations of mesophilic bacteria (mean 156 cfu/m^3), Aspergillus fumigatus (mean 264 cfu/m^3) and gram negative bacteria (mean 4 cfu/m^3) at the location downwind of the quarry green waste composting area were all below appropriate levels suggested by the Environment Agency/NRW, representing 16%, 53% and 2% of the guidance values, respectively. The sampling location downwind of the quarry composting area conformed to the requirements of the protocol closely during all samples, being between 3^o and 5^o from directly downwind during samples.

At present, there are no statutory levels that exist in order to put the results in to a regulatory context only the guidance values set by the Environment Agency for total bacteria, gram-negative bacteria and *Aspergillus fumigatus*.

In accordance with the precautionary principle, it is recommended that practical risk mitigation measures are employed to minimise liberation of bioaerosols as far as is reasonably practical. Practical risk mitigation measures recommended to minimise bioaerosol release, during processes such as turning, shredding and screening, are detailed in Section 9.0 – Recommendations, page 33.

1.0 Introduction

At the request of Bryn Group Ltd, the Centre for Health, Safety and Environment (CHSE) carried out a monitoring exercise to assess levels of bioaerosol released from AD and green waste composting operations at the Bryn Group Ltd facility at Gelliargwellt Farm, Gelligaer, Hengoed. The monitoring was undertaken to address the requirements of the Bryn Group Ltd Environmental Permit: (WP3995FY/V004). The current monitoring was undertaken on 09th October 2018.

On the 01st April 2013, NRW was formed as the regulatory authority in Wales by combination of the functions of the Environment Agency, Countryside Council for Wales and the Forestry Commission in Wales. Natural Resources Wales (NRW) utilise the protocols and guidance on bioaerosols published and adopted by the Environment Agency. The analysis and report has therefore been prepared with reference to Environment Agency appropriate levels and guidance. References to policy and guidance from the Environment Agency within the text therefore also refer to NRW. The Environment Agency Technical Guidance Note (TGN): M9, Environmental monitoring of bioaerosols at regulated facilities, is in the process of being adopted by NRW. The date of adoption has not been announced as yet. The monitoring and analysis for this report have therefore been undertaken in line with the AfOR protocol, '*A standard protocol for the monitoring of bioaerosols at open composting facilities*' (2009).

2.0 Potential Health Effects

Bioaerosols are defined as a collection of aerosolised biological particles including actinomycetes, bacteria, fungi protozoa and their components (Millner et al 1994, Millner, 1995, Gilbert and Ward, 1998; Van der Werf, 1996, Epstein, 1994; Fischer et al 1999, Cox and Wathes, 1995). These organisms are fundamental to the decomposition of organic wastes. The concern regarding bioaerosols from waste processing activities arises because of their potential to cause adverse health effects in employees and the public living in close proximity to such facilities. These adverse effects can potentially occur in susceptible individuals from exposure to the micro-organisms associated with the decomposition of organic wastes and can elicit an adverse response by infection, allergy or an adverse response to toxins (Environment Agency, 2005). According to Swan *et al.* (2003) the effects of exposure to organic dust on respiratory health may lead to or exacerbate a number of distinct identifiable conditions including Aspergillosis in immuno-compromised individuals (Millner *et al*,1994, Millner 1995), Allergic Rhinitis and Asthma (Zuskin *et al*, 1994), Extrinsic allergic alveolitis (Farmers Lung) (Flannigan *et al* 1991) where prolonged (usually occupational) exposure occurs, Chronic Obstructive Pulmonary Disease (COPD) (Lacey and Crook, 1988, Matheson, 2005); Toxic Pneumonitis (Lacey and Crook,1988) and upper airway irritation/mucous membrane irritation (Dutkiewicz,1997).

Risk to the public

Whilst many measurements of airborne concentrations of organisms have been made within and in the vicinity of in-vessel and open windrow composting plants, which give ample evidence for a hazard especially to composting workers, there have been very few studies of health effects from which any quantitative indication of risk can be derived for members of the public (IOM, 2008). Concern has been raised by residents in the vicinity of waste processing facilities that composting activities could increase levels of bioaerosols, such as airborne *Aspergillus fumigatus* spores. Most reports show numbers to have declined to 'background' within 200 m from a compost bioaerosol source, although some report levels above background at a greater distance. Background or typical ambient bioaerosol levels may differ by orders

of magnitude depending on location, weather and season, which hinder interpretation. Few published studies exist where the health of residents near composting sites has been investigated, but where such work has been done there is little evidence of ill health compared to controls (Millner, 1995). The responses to bioaerosols are host and dose dependent; that is some individuals may respond to a dose that does not affect others (Millner et al., 1994, Millner 1995). However based on the current knowledge, the risk is impossible to quantify due to the lack of accepted dose-response relationships for bioaerosol exposure (Wheeler et al, 2001; IOM, 2008; Drew et al, 2009; EA, 2009). Bioaerosols are endemic in the environment from decomposing leaves in gardens and woods, wheat fields etc. and the body has many natural defences against them. However, individual susceptibilities vary considerably and even natural levels of bioaerosols can be harmful to certain individuals. The Environment Agency (EA) has established conservative *'acceptable levels' for* micro-organisms in air as shown in Table 1 (Drew et al, 2009). The EA concede that other activities may lead to higher background bioaerosol levels than would normally be expected (EA, 2007).

Table: 1

Environment Agency Reference for Bioaerosol (Drew et al, 2009)	
Reference Pollutant	CFU m^{-3}
Total Bacteria	1000
Aspergillus fumigatus	500
Gram-negative Bacteria	300

3.0 Monitoring Protocol

The monitoring was undertaken in accordance with the current AfOR guidance, "*A Standardised Protocol for the Monitoring of Bioaerosols at Open Composting Facilities*" (2009). The Environment Agency Technical Guidance Note: M9, Environmental monitoring of bioaerosols at regulated facilities, is currently being adopted by NRW. NRW are due to issue a position statement on the implementation of the M9 protocol.

Bioaerosols were sampled at a position 1.5m above ground level using a single stage Anderson sampler during normal site operations. Sampling was conducted in parallel at each of the monitoring locations. Sampling at the Upwind location was undertaken concurrently with the sampling at the Downwind location. Additional passive samples, i.e. no air drawn through the sampler, were taken at the locations downwind of the working areas.

4.0 Sample Collection

Processing of food and green waste, at Bryn Group Ltd, are carried out in two areas of the facility:

- food waste is processed using an Anaerobic Digestion process, housed in purpose built sealed vessels. Waste is delivered and prepared for the process in the reception building. The reception building has two open bed woodchip biofilters.
- an area for green waste composting, using open windrows, located at the western end of the sandstone quarry.

Table 2 details the distances and bearing of the closest receptors to the two working areas.

Table 2 – Sensitive Receptors

Receptor	From AD Reception building		From quarry		Description
	Distance	Bearing	Distance	Bearing	
Farm outbuildings	25m	130°	125m	310°	Outbuildings of Gelliargwellt Uchaf Farm
Snack bar	100m	70º	300m	330°	Hot food takeaway.
Gelliargwellt Farm House	125m	160º	90m	310º	Farm house, residential building.
Weighbridge and office	150m	170°	230m	270°	Site building for Bryn Quarry.
Green Acres	250m	329°	640m	325°	Residential.
Alpine Cottages	270m	328°	670m	320°	Residential Houses
Tophill Farm	350m	330º	740m	325°	Farm house, outbuildings and cattle sheds
House	550m	280°	840m	300°	Residential.
Claerwen, Gelligaer	560m	65°	500m	45°	Residential Street
Standing Stone, Claerwen	700m	90°	530m	60°	Residential. Requested monitoring location.

In accordance with the Association for Organics Recycling protocol, monitoring locations are adjusted on each monitoring occasion, to account for changes in the prevailing wind direction, site access and other practical issues. The actual monitoring locations utilised are included in Appendix 2, page 37, and indicated as:-

- Up-wind AD (UW)
- Downwind AD/Sensitive Receptor (Snack Bar) (DW)
- Up-wind Quarry (UWQ)
- Downwind Quarry (DWQ)

4.1. Selection of Monitoring Locations

On arrival at the site on the day of monitoring, the weather station was erected on the edge of the sandstone quarry, away from buildings and trees that may affect meteorological data. From gathered data, a working plan was proposed and monitoring locations selected. The meteorological data was consulted between each monitoring location to ensure that selected monitoring locations were still valid, prior to setting up equipment. A compass (Silva Sweden AB) was used to measure bearings to and from monitoring locations and the working area during monitoring. Distances between monitoring locations and the working area were calculated using a handheld GPS device (Garmin, USA), which had a resolution of +/- 4m.

On the day of monitoring, windrows in the quarry area were screened. The prevailing wind direction was a south westerly wind, i.e. blowing from the direction of Nelson, over the facility and towards Gelligaer. Monitoring was carried out at four locations: a location upwind of the AD reception on the bund between the farm lagoon and the AD facility (UW), a point downwind of the AD reception building on the edge of the vehicle parking area adjacent the snack bar receptor (DW), allocation upwind of the greenwaste composting area in the quarry, close to the quarry entrance (UWQ) and a location downwind of the quarry working area, on land to the east of the Gelliargwellt Farm cattle sheds (DWQ).

Outlined below, in sequence, are the rationales for selection of the monitoring locations:

Upwind AD/Biofilter (UW) – The prevailing wind direction when planning the monitoring locations at the AD Reception was south westerly. Selection of a suitable monitoring location was complicated by the presence of the access road to the AD Reception, wood waste shredding building and stockpiles of empty waste skips. A location was found on the bund around the AD yard area, between the AD facility and the farm lagoon. This location was approximately 110m from the reception building and closest biofilter. This is

slightly greater than the 25m to 50m stipulated in the protocol but was the most practical location on the day.



Photograph 1: Upwind monitoring location, looking towards working area.



Photograph 2: Upwind monitoring location, looking upwind.

Downwind of the AD area (DW) – From consulting the meteorological station prior to monitoring, the most suitable location for the downwind sample was in the field to the North East of the access road to the facility. It was noted when selecting where to place the samplers that lorries used the passing place on the access road as a waiting/rest stop (Photograph 3). This would be between the site and the samplers, effectively screening the samplers.

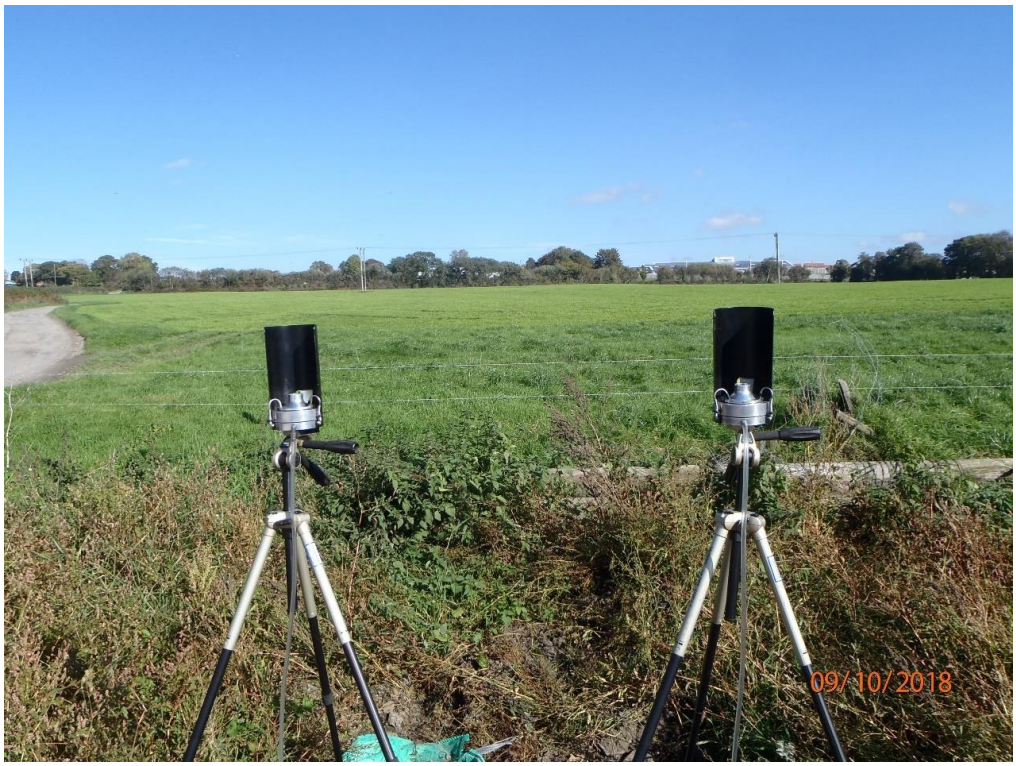


Photograph 3: Preferred downwind sampling location, showing vehicle parked in the passing place.

A downwind monitoring location was chosen away from the passing place but as close to the downwind location as possible. The samplers were placed on the edge of the access to the cattle buildings of Gelliargwellt Farm. This location was also the closest practical location for monitoring at the snack bar receptor. The practical monitoring location is slightly further from the working area (110m) than the snack bar receptor (100m) and so may slightly underestimate the likely bioaerosol concentration were the receptor downwind.



Photograph 4: Downwind AD monitoring location, looking towards working area.



Photograph 5: Downwind AD monitoring location, looking downwind.

Upwind of the quarry (UWQ) – A monitoring location between 25m and 50m upwind of the greenwaste composting area in the quarry would have placed the monitoring location on the access road to the quarry. A location was

chosen upwind of the quarry, away from traffic but as close to the working area as possible. The monitoring location used was 60m upwind of the greenwaste composting area at the edge of an area of open grazing land, adjacent to the access road.



Photograph 6: Upwind quarry monitoring location, view towards working area.



Photograph 7: Upwind quarry monitoring location, looking upwind.

Downwind of the quarry (DWQ/SR) – On the day of monitoring, the prevailing southerly – south westerly wind meant that the downwind monitoring location was located on the north east side of the quarry. A location was found close to a shallow pool on an area of ground where top soil had been removed. The monitoring location was separated from the working area by a bund on the top of the quarry edge, which meant that the working area was not visible from the monitoring location. The samplers were placed in front of small trees along a field boundary, 60m from the edge of the working area. This follows the recommendation for siting downwind samples where there is an intervening structure or installation (AfOR 2009, Pg. 14). This location was closer to the working area than the receptor at Gelliargwellt Farm House (90m) and may therefore overestimate the concentrations likely, were the receptor downwind. This was the most practical location for the samplers.



Photograph 8: Downwind quarry monitoring location, looking towards working area.



Photograph 9: Downwind quarry monitoring location, looking downwind.

4.2. Site Activity

Windrows in the quarry were screened between 08.00 and 12.00.

Shredding of material was undertaken in the AD reception throughout the monitoring period. Food waste was delivered to the AD reception area by refuse vehicles between 11.00 and 13.00.

5.0 Meteorological Data

Meteorological data was logged with a Kestrel Instruments 5500 Weather Meter (Neilsen-Kellerman, Minneapolis, USA) throughout the monitoring period. Wind speed, wind direction, temperature and atmospheric pressure were logged every minute by the weather meter from 08.00 to 13.20. The full meteorological data has been omitted from the report due to the large volume that is generated. However, supplementary meteorological data that provides a general overview is listed in Appendix 4.

The weather on the day of monitoring was dry and sunny with no more than 2/8 cloud cover throughout monitoring. There was no precipitation during the monitoring period. The prevailing wind direction during the monitoring period moved slightly through the day, starting southerly and ending south westerly by the end of sampling. The overall prevailing wind (calculated as a mean of the wind directions recorded for the time on site, 08.00 to 13.20) was from a south south westerly direction. The wind speed was similar throughout the day, with an average wind speed of 2.7 m/s over the monitoring period (calculated as a mean of recorded wind speeds for the time on site, 08.00 to 13.20). The temperature rose during the day from 8.1 ^{o}C to 13.3 ^{o}C. Humidity fell slightly during the day and ranged from 82% to 72%.

Weather conditions for the 24 hours prior to the monitoring exercise were:
Sunny with a south easterly wind. There was no precipitation in the previous 24 hours.

Calculation of average wind speed and average wind direction during sampling periods, were calculated as vector components in accordance with AfOR protocol (2009), Appendix, Page 30.

6.0 Analysis

Analysis was carried out for total mesophilic bacteria, the fungi *Aspergillus fumigatus*, and gram negative bacteria using standard 'Cardiff Met Laboratory Protocol' and in line with BS7218:2007 + A1:2013 Microbiology of food and animal feeding stuffs – General requirements and guidance for microbiological examinations.

This method is taken from the protocol, "A Standardised Protocol for the Monitoring of Bioaerosols at Open Composting Facilities" (AFOR, 2009).

6.1 Selective Media

All laboratory media preparation and sterilisation was carried out in accordance with the standard procedures as set out in the Cardiff School of Health Sciences Laboratory Manual (volume 2, section 5) in line with BS EN ISO 7218:2007 + A1:2013 – "Microbiology of food and animal feeding stuffs. General requirements and guidance for microbiological examinations." and ISO 11133-1:2009 (ISO, 2009).

Half-strength nutrient agar medium is used to culture mesophilic bacteria; malt extract medium was used to culture *Aspergillus fumigatus* and MacConkey No.3 agar was used to culture Gram Negative bacteria. 40ml of media was poured in to each petri dish to ensure that the correct distance was maintained between the sampling orifice and media surface in the Andersen samplers.

The mesophilic bacterial count and count for *Aspergillus fumigatus* followed the process for colony enumeration contained in the AfOR protocol (2009). The total gram-negative count method is not covered by the AfOR protocol, but is based on reference by Drew et al (2009).

6.2 Sampling

The sampling at the composting site follows the procedures laid out in the guidance, "A Standardised Protocol for the Monitoring of Bioaerosols at Open Composting Facilities" (AFOR, 2009).

The exposure time for each sample was 20 minutes at all locations. Samples at the upwind and downwind locations were exposed concurrently.

Petri dishes were stored in a cooled container (at approximately 4°C) following sampling, until all remaining samples had been collected. All dishes were then inverted and placed in an appropriate microbiological incubator at the same time. This is carried out no later than 12 hours after sampling. The nutrient agar medium, selecting for mesophilic bacteria and the MacConkey No. 3 agar medium, culturing for total Gram Negative bacteria were incubated at 37°C. Colonies growing on these media were enumerated after two and three days respectively.
The malt extract medium, culturing for *Aspergillus fumigatus*, were incubated at 42°C and enumerated after 2 days.

6.3 Enumeration

Mesophilic Bacteria:
The number of colonies on each nutrient agar medium plate were counted after incubation of the sample for two days at 37°C.
If 399 or more colonies are counted on any single plate, this is recorded as "Too Numerous To Count" (TNTC).

Gram Negative Bacteria:
The number of colonies of Gram Negative bacteria growing on each MacConkey No. 3 agar plate after incubation of the sample for three days at 37°C were counted and recorded.
If 399 or more colonies are counted on any single plate, this is recorded as "Too Numerous To Count" (TNTC).

Aspergillus fumigatus:
The number of colonies of *Aspergillus fumigatus* growing on each malt extract agar medium plate after incubation of the sample for two days at 40°C were counted and recorded. Identification is based upon gross colony colour and morphology plus spore bearing structures according to standard texts.

Identification was confirmed by low magnification bright field light microscopy where necessary.

If enumeration of *Aspergillus fumigatus* is not possible because of the large number of colonies, this is recorded as “Too Numerous To Count” (TNTC).
Where spreading colonies of other fungi obscure less than half of a Petri dish, then colonies of *Aspergillus fumigatus* were enumerated on the un-obscured half, as long as this appears to be representative of the entire sample. This is recorded and the number of colonies adjusted as if the whole dish were enumerated.

Only colonies that fall at the impaction sites of the sampler were counted and recorded. Satellite colonies growing adjacent to larger colonies at the impaction site and colonies growing around the perimeter of the medium are ignored.

If spreading colonies obscured more than half of one Petri dish, this was recorded as “No results, spreaders”. If 399 or more colonies are counted on any single plate, this is recorded as “Too Numerous To Count” (TNTC).

Where spreading colonies obscure less than half of a Petri dish, then colonies were enumerated on the un-obscured half, as long as this appears to be representative of the entire sample. This is recorded and the number of colonies adjusted as if the whole dish were enumerated.

6.4 Data Recording

Laboratory – prior to sampling:

- Date and time of media preparation (media preparation log file)
- Batch numbers of the media components (media preparation log file)
- Laboratory personnel (media preparation log file)
- Trace of the sterilisation temperature profiles (refer to Cardiff Met Laboratory Manual volume 2, section 5.6 “Media Autoclaving” and section 9.22 “Osprey Multicycle Autoclave”)
- Storage conditions of the prepared media (media preparation log file)

Laboratory -post sampling:

For each Petri dish the following was recorded,

- Unique sample number
- Sampling date
- Date and time Petri dishes were placed in incubators
- Date and time Petri dishes were removed from incubators
- Number of colonies on the plate
- Corrected number of colonies (using the Positive Hole Correction Table supplied by the Andersen sampler manufacturer)

7.0 Results

The data interpretation has been conducted and presented in accordance with the AFOR guidance, "*A Standardised Protocol for the Monitoring of Bioaerosols at Open Composting Facilities*" (2009).

In the tabulated results below;

- *'UW' refers to the location upwind of the AD facility*
- *'DW' refers to the sample location downwind of the AD facility*
- *'UWQ' refers to the location upwind of the quarry greenwaste composting area*
- *'DWQ' refers to the sample location downwind of the quarry greenwaste composting area*
- *'*½Str Nutrient' refers to the ½ strength nutrient agar media
- *'*MacConkey' refers to the MacConkey No. 3 agar media
- *'*Malt extract' refers to the Malt extract media
- *'AF' refers to Aspergillus fumigatus*
- *'MB' refers to Mesophilic Bacteria*
- *'GN' refers to Gram Negative Bacteria*
- *'Passive' refers to a sample left in the sampler but with no vacuum applied*
- *'Control' refers to a sample not exposed to the atmosphere before analysis*
- *TNTC is indicated when enumeration is not possible because of the large numbers of colonies. This is greater than 399 colonies or greater than 2427 cfu m^{-3}*
- *cfu m^{-3} refers to Colony forming units per cubic meter of air*
- *'Corrected Number of colonies' refers to the number of colonies per plate adjusted using the Positive Hole Correction Table*

The results presented below are for each organism for the monitoring exercise undertaken on 09th April 2018. A graphical overview of the results can be found in Appendix 1, page 35. A summary of past monitoring results can be found in Appendix 5, page 44.

Mesophilic Bacteria Counts – 09th October 2018

Sample Reference Number	Media	Incubation Period		Identification	Date Completed	Presumptive count (colonies per plate)	Sample Duration	Flow Rate	Corrected Number of colonies*	**Colony forming units per cubic meter of air (cfu m-3)**
		IN	OUT							
DW MB Passive	½Str Nutrient	09/10/2018	11/10/2018	n/a	11/10/2018	0	n/a	0	0	n/a
DWQ MB Passive	½Str Nutrient	09/10/2018	11/10/2018	n/a	11/10/2018	0	n/a	0	0	n/a
Control 1	½Str Nutrient	09/10/2018	11/10/2018	n/a	11/10/2018	0	n/a	n/a	n/a	n/a
Control 2	½Str Nutrient	09/10/2018	11/10/2018	n/a	11/10/2018	0	n/a	n/a	n/a	n/a
UW MB 1	½Str Nutrient	09/10/2018	11/10/2018	n/a	11/10/2018	123	15	0.0283	147	**346**
UW MB 2	½Str Nutrient	09/10/2018	11/10/2018	n/a	11/10/2018	112	15	0.0283	131	**309**
DW MB 1	½Str Nutrient	09/10/2018	11/10/2018	n/a	11/10/2018	160	15	0.0283	204	**481**
DW MB 2	½Str Nutrient	09/10/2018	11/10/2018	n/a	11/10/2018	142	15	0.0283	175	**412**
UWQ MB 1	½Str Nutrient	09/10/2018	11/10/2018	n/a	11/10/2018	5	15	0.0283	5	**12**
UWQ MB 2	½Str Nutrient	09/10/2018	11/10/2018	n/a	11/10/2018	6	15	0.0283	6	**14**
DWQ MB 1	½Str Nutrient	09/10/2018	11/10/2018	n/a	11/10/2018	66	15	0.0283	72	**170**
DWQ MB 2	½Str Nutrient	09/10/2018	11/10/2018	n/a	11/10/2018	56	15	0.0283	60	**141**

Total Gram Negative Bacteria Counts – 09th October 2018

Sample Reference Number	Media	Incubation Period		Identification	Date Completed	Presumptive count (colonies per plate)	Sample Duration	Flow Rate	Corrected Number of colonies*	**Colony forming units per cubic meter of air (cfu m-3)**
		IN	OUT							
DW GN Passive	MacConkey	09/10/2018	12/10/2018	n/a	12/10/2018	0	n/a	0	0	n/a
DWQ GN Passive	MacConkey	09/10/2018	12/10/2018	n/a	12/10/2018	0	n/a	0	0	n/a
Control 1	MacConkey	09/10/2018	12/10/2018	n/a	12/10/2018	0	n/a	n/a	n/a	n/a
Control 2	MacConkey	09/10/2018	12/10/2018	n/a	12/10/2018	0	n/a	n/a	n/a	n/a
UW GN 1	MacConkey	09/10/2018	12/10/2018	n/a	12/10/2018	0	15	0.0283	0	**0**
UW GN 2	MacConkey	09/10/2018	12/10/2018	n/a	12/10/2018	0	15	0.0283	0	**0**
DW GN 1	MacConkey	09/10/2018	12/10/2018	4 G-ve	12/10/2018	4	15	0.0283	4	**9**
DW GN 2	MacConkey	09/10/2018	12/10/2018	1 G-ve	12/10/2018	1	15	0.0283	1	**2**
UWQ GN 1	MacConkey	09/10/2018	12/10/2018	1 G-ve	12/10/2018	1	15	0.0283	1	**2**
UWQ GN 2	MacConkey	09/10/2018	12/10/2018	n/a	12/10/2018	0	15	0.0283	0	**0**
DWQ GN 1	MacConkey	09/10/2018	12/10/2018	1 G-ve	12/10/2018	1	15	0.0283	1	**2**
DWQ GN 2	MacConkey	09/10/2018	12/10/2018	2 G-ve	12/10/2018	2	15	0.0283	2	**5**

Aspergillus fumigatus **Counts – 09th October 2018**

Sample Reference Number	Media	Incubation Period		Identification	Date Completed	Presumptive count (colonies per plate)	Sample Duration	Flow Rate	Corrected Number of colonies*	**Colony forming units per cubic meter of air (cfu m-3)**
		IN	OUT							
DW AF Passive	Malt Extract	09/10/2018	11/10/2018	n/a	11/10/2018	0	n/a	0	n/a	n/a
DWQ AF Passive	Malt Extract	09/10/2018	11/10/2018	n/a	11/10/2018	0	n/a	0	n/a	n/a
Control 1	Malt Extract	09/10/2018	11/10/2018	n/a	11/10/2018	0	n/a	n/a	n/a	n/a
Control 2	Malt Extract	09/10/2018	11/10/2018	n/a	11/10/2018	0	n/a	n/a	n/a	n/a
UW AF 1	Malt Extract	09/10/2018	11/10/2018	3 +ve *A. fumigatus*	11/10/2018	3	15	0.0283	3	**7**
UW AF 2	Malt Extract	09/10/2018	11/10/2018	2 +ve *A. fumigatus*	11/10/2018	2	15	0.0283	2	**5**
DW AF 1	Malt Extract	09/10/2018	11/10/2018	65 +ve *A. fumigatus*	11/10/2018	65	15	0.0283	71	**167**
DW AF 2	Malt Extract	09/10/2018	11/10/2018	76 +ve *A. fumigatus*	11/10/2018	76	15	0.0283	84	**198**
UWQ AF 1	Malt Extract	09/10/2018	11/10/2018	1 +ve *A. fumigatus*	11/10/2018	1	15	0.0283	1	**2**
UWQ AF 2	Malt Extract	09/10/2018	11/10/2018	n/a	11/10/2018	0	15	0.0283	0	**0**
DWQ AF 1	Malt Extract	09/10/2018	11/10/2018	99 +ve *A. fumigatus*	11/10/2018	99	15	0.0283	114	**269**
DWQ AF 2	Malt Extract	09/10/2018	11/10/2018	96 +ve *A. fumigatus*	11/10/2018	96	15	0.0283	110	**259**

During monitoring, windrows in the quarry were screened between 08.00 and 12.00. Shredding of material was undertaken in the AD reception throughout the monitoring period. Food waste was delivered to the AD reception area by refuse vehicles between 11.00 and 13.00. Samples at the upwind and downwind monitoring locations were exposed concurrently. Exposure times were reduced from 20 minutes to 15 minutes for all samples to ensure that the sampling was carried out while active composting/AD activities were undertaken during sample collection.

All concentrations of bioaerosols measured on 09th October 2018 at the Bryn Group facility were below guidance levels suggested by the Environment Agency of 1000 cfu/m^3 for mesophilic bacteria, 500 cfu/m^3 for the fungi *Aspergillus fumigatus* and 300 cfu/m^3 for gram-negative bacteria.

Concentrations of mesophilic bacteria (mean 447 cfu/m^3), Aspergillus fumigatus (mean 183 cfu/m^3) and gram-negative bacteria (mean 6 cfu/m^3) at the location downwind of the AD facility were all below appropriate levels suggested by the Environment Agency/NRW. The difference in bearing of the sampling location to the prevailing wind direction was 3^o during mesophilic bacteria and gram-negative samples and 26^o during the *Aspergillus fumigatus* sample which conform to the requirements of the protocol. The monitoring location used was the most practical available and is slightly further from the working area (110m) than the snack bar receptor (100m). The sampling location may therefore slightly underestimate the likely bioaerosol concentration were the receptor downwind. The concentrations recorded represent 45%, 37% and 2% of the appropriate levels suggested by the Environment Agency for mesophilic bacteria, Aspergillus fumigatus and gram-negative bacteria, respectively.

The topography between the sampling location and the AD facility consisted of a rocky outcrop and overhanging mature trees. This is the same as the topography between the AD reception and sensitive receptor.

Concentrations of all components measured at the upwind location, on the bund between the AD facility and the farm lagoon (mesophilic bacteria: mean 348 cfu/m^3, *Aspergillus fumigatus*: mean 6 cfu/m^3 and gram-negative bacteria: not detected)

were below the guidance levels suggested by the Environment Agency. The elevated concentrations of mesophilic bacteria at the location suggests an influence from a bioaerosol source upwind, for example the farm lagoon. Selection of the upwind sampling location was problematic due to the presence of buildings, the access to the facility and stored skips. The difference in bearing of the sampling location to the prevailing wind direction varied between 220^{o} and 226^{o} during samples. Although this is slightly greater than the tolerance of 30o from directly upwind/downwind suggested by the Environment Agency, this still represents a sample upwind of the facility. The protocol recommends that the upwind sample should be taken between 25m and 50m upwind of the site to ensure that the sample is not affected by emissions from the site but is also close enough to minimise bioaerosols from other sources. A shorter distance was not practical on the day, as it would have placed the sampling location either on the access to the AD facility or amongst other structures. The location selected was the most practical on the day of monitoring.

Concentrations of mesophilic bacteria (mean 156 cfu/m^{3}), *Aspergillus fumigatus* (mean 264 cfu/m^{3}) and gram negative bacteria (mean 4 cfu/m^{3}) at the location downwind of the quarry green waste composting area were all below appropriate levels suggested by the Environment Agency/NRW. The difference in bearing of the sampling location to the prevailing wind direction varied between 3^{o} and 5^{o} during the downwind monitoring location samples. The location used closely complies with the downwind requirement of the protocol. In order to avoid the screening effect of a tree lined boundary wall the samplers were placed upwind of the obstacle. The sampling location was 60m from the active working area, which is a smaller distance than the distance from the working area to the closest receptor (90m). Therefore, the monitoring location used may overestimate the likely bioaerosol concentrations downwind if the sensitive receptor were downwind of the quarry working area.

Concentrations of all components measured upwind of the quarry composting area (mesophilic bacteria: mean 13 cfu/m^{3}, *Aspergillus fumigatus*: mean 1 cfu/m^{3} and gram-negative bacteria: mean 4 cfu/m^{3}) were low and well below the guidance levels suggested by the Environment Agency. The protocol recommends that the upwind sample should be taken between 25m and 50m upwind of the site to ensure that the

sample is not affected by emissions from the site but is also close enough to minimise bioaerosols from other sources. The sampling location used was 60m from the active working area, as a location closer was impractical due to the access road to the quarry for composting and quarrying traffic.

At present, there are no statutory levels to place the measured concentrations in a regulatory context. However, guidance levels suggested by the Environment Agency exist to assist with the interpretation of these results. In comparison with the guidance levels, the likelihood of adverse health effects from exposure to bioaerosols of this magnitude is low. In accordance with the precautionary principle, it is recommended that practical risk mitigation measures are employed to minimise liberation of bioaerosols as far as is reasonable practical.

8.0 Conclusions

In conclusion, the CHSE / Cardiff Met have completed ambient air monitoring of bioaerosols in accordance with Association for Organics Recycling approved methodology. Selective media has been used to enumerate mesophilic bacteria, the fungus *Aspergillus fumigatus* and gram-negative bacteria.

During monitoring, material was shredded and deliveries made to the AD reception. Material in the quarry composting area was screened.

Bioaerosol levels recorded during the monitoring exercise on 09th October 2018 were below the appropriate levels set by the Environment Agency of 1000 cfu/m^3 for mesophilic bacteria, 300 cfu/m^3 for gram-negative bacteria and 500 cfu/m^3 for *Aspergillus fumigatus*, at all locations monitored.

Practical control measures are provided in Section 9.0 – Recommendations.

9.0 Recommendations

Practical risk mitigation measures are recommended to minimise bioaerosol exposure through processes such as turning, shredding and screening. The Environment Agency Technical Guidance on Composting Operations (October 2001 – Draft for External Consultation) recommends the following;

- The moisture content within all stages of the composting process should be monitored to avoid the waste and materials drying out and potentially forming dusts.
- The formation or turning of windrows or piles should be avoided if possible on windy days. Screening and shredding should also be undertaken when wind speeds are calm or wind direction is away from sensitive receptors.
- Site surfaces such as roads and tracks and the piles or windrows themselves should be regularly dampened down and/or regularly swept to suppress dust.
- Plant and machinery should be well maintained to avoid dust generation. The use of enclosures for screens and hoppers can be useful.
- Physical barriers such as mounds or walls can prevent dust leaving a site. Site construction and specific landscaping techniques can contain dusts that are generated on site.
- The composting of waste within buildings can provide excellent containment for the control of dust.

In addition to the recommendations in the Technical Guidance note, it is recommended that:

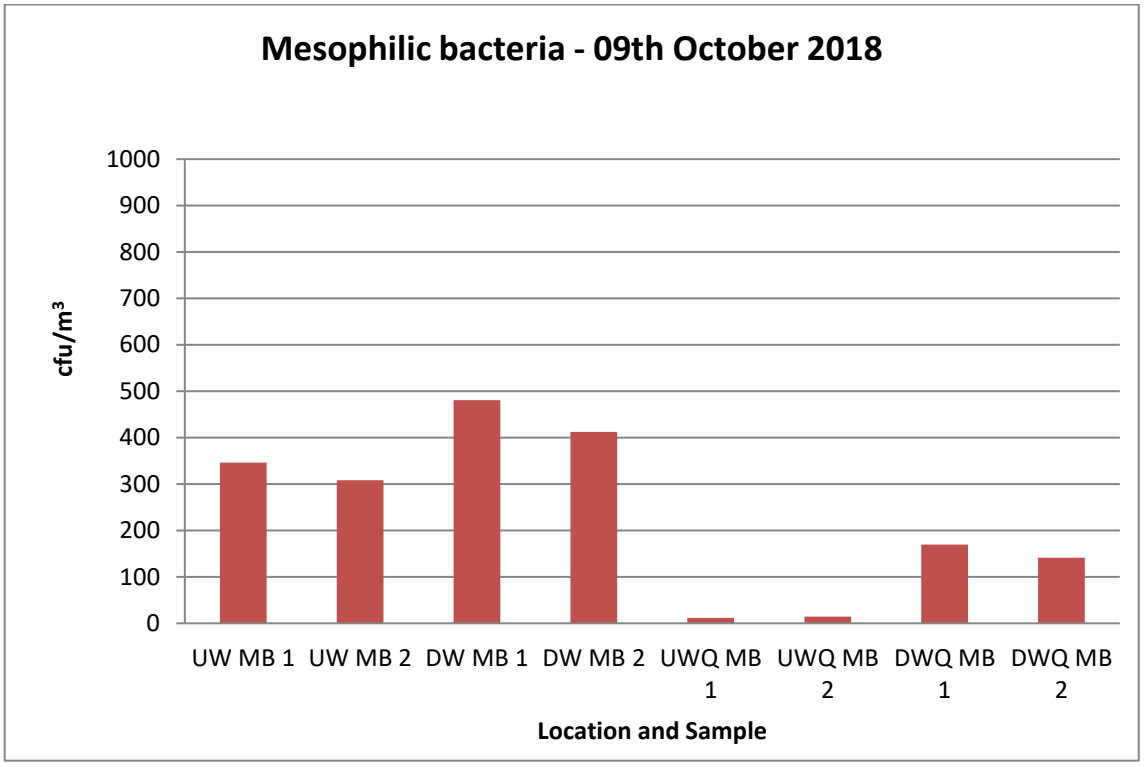
- Drop heights should be minimised.
- Vehicle speeds limits should be strictly observed and enforced.

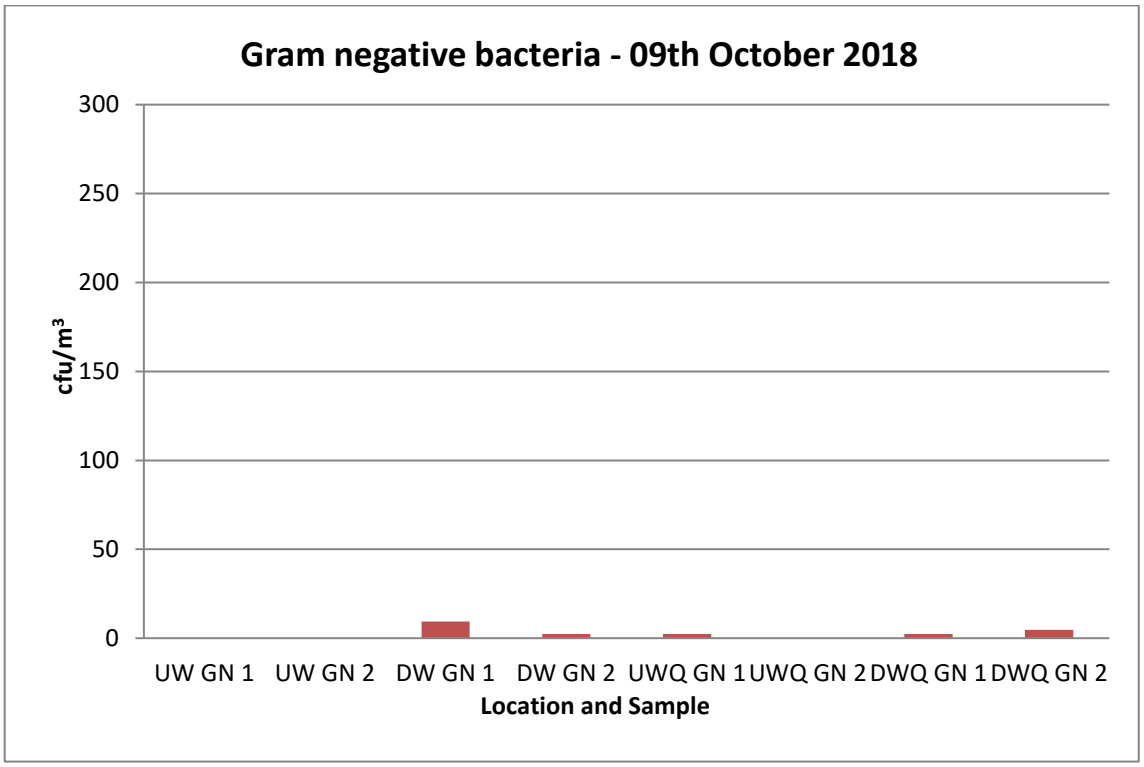
It is recommended that this sampling methodology is continued at quarterly intervals to establish trends in bioaerosol release and dispersion and to assess the impact of operational controls.

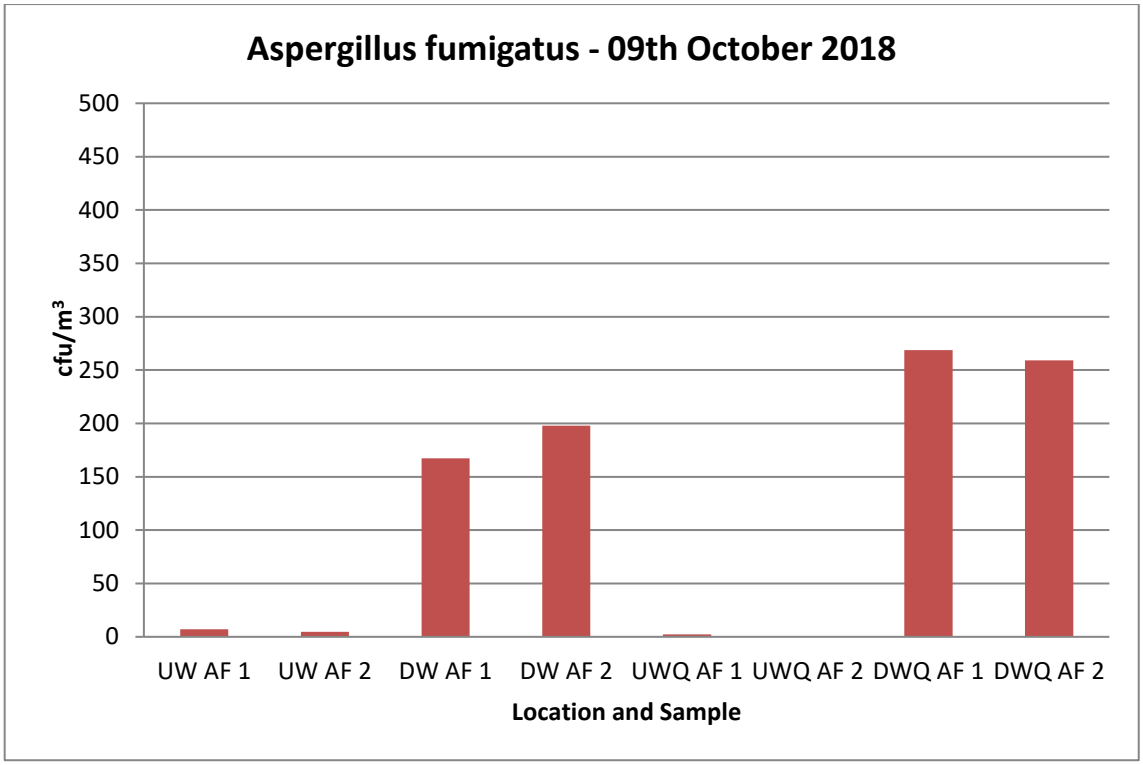
Appendices

Appendix 1 – Variation in monitored levels of specific microorganisms

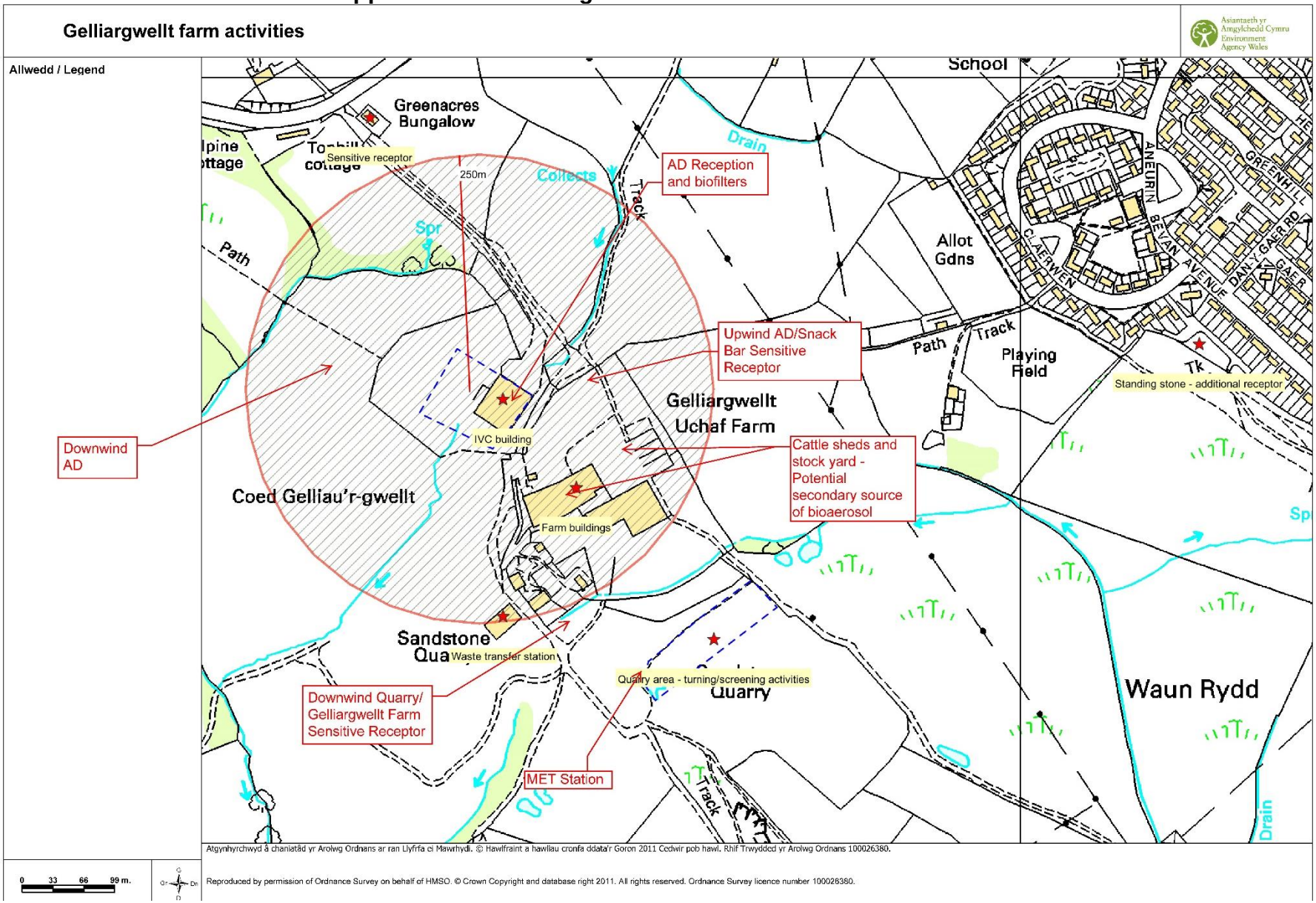
09th October 2018






Aspergillus fumigatus - 09th October 2018
500
450
400
350
300
250
200
150
100
50
0
cfu/m³
UW AF 1
UW AF 2
DW AF 1
DW AF 2
UWQ AF 1
UWQ AF 2
DWQ AF 1
DWQ AF 2
Location and Sample

Appendix 2 Monitoring Location Plan – 09th October 2018



NB: A new plan of the Bryn Group operations at Gelliargwellt Uchaf is currently being prepared. The new plan, showing recent developments, such as the AD facility, new lagoon and MRF will be used as soon as it is available.

Appendix 3 – Location Specific Site Data

Upwind AD/biofilter Location – 09th October 2018

Up Wind AD

Site: Bryn Quarry, Gelliargwellt Farm, Gelligaer

Site Operator: Bryn Compost Ltd

Sampling Date: 09/10/2018

Commissioning Laboratory: Cardiff Met, Western Avenue, Llandaff, Cardiff

Estimated Mass of Material:

Type of Material Processed on site: In-Vessel Mixed Food and Green Waste

Location:	Sampling Reference Number:	Difference from boundary of operational area or tuning / screening operation (m)	Difference in bearing location of samplers from boundary / source and mean direction wind blows to (o)	Sampling time: (hh:mm)	Sampling duration (min)	Microbial type	Site activity	Material processed	Calculated concentration of airborne micro-organisms (cfu m-3)	Arithmetic mean of parallel samples (cfu m-3)	Comments relating to any activities occurring during the sampling period that might affect the concentration of airborne micro-organisms
Upwind AD	AF UW 1	70.0	226	12.05	15	AF	Receiving and shredding waste in Reception building.	Source separated food waste.	7	6	
Upwind AD	AF UW 2	70.0	226	12.05	15	AF			5		
Upwind AD	MB UW 1	70.0	221	12.24	15	MB			147	139	
Upwind AD	MB UW 2	70.0	221	12.24	15	MB			131		
Upwind AD	GN UW 1	70.0	220	12.41	15	GN			0	0	
Upwind AD	GN UW 2	70.0	220	12.41	15	GN			0		

Distances and bearings given in the above table refer to distance/bearing from the Anaerobic Digester area.

Downwind AD/Biofilter

Site: Bryn Quarry, Gelliargwellt Farm, Gelligaer
Site Operator: Bryn Compost Ltd
Sampling Date: 09/10/2018
Commissioning Laboratory: Cardiff Met, Western Avenue, Llandaff, Cardiff
Estimated Mass of Material:
Type of Material Processed on site: Post IVC mixed food and green waste.

Location:	Sampling Reference Number:	Difference from boundary of operational area or turning / screening operation (m)	Difference in bearing location of samplers from boundary / source and mean direction wind blows to (o)	Sampling time: (hh:mm)	Sampling duration (min)	Microbial type	Site activity	Material processed	Calculated concentration of airborne micro-organisms (cfu m-3)	Arithmetic mean of parallel samples (cfu m-3)	Comments relating to any activities occurring during the sampling period that might affect the concentration of airborne micro-organisms
Downwind	AF DW 1	110.0	24	11.59	15	AF	Receive and shred waste in Reception building.	Source separated food waste.	167	183	
Downwind	AF DW 2	110.0	24	11.59	15	AF			198		
Downwind	MB DW 1	110.0	9	12.17	15	MB			481	447	
Downwind	MB DW 2	110.0	9	12.17	15	MB			412		
Downwind	GN DW 1	110.0	9	12.34	15	GN			9	6	
Downwind	GN DW 2	110.0	9	12.34	15	GN			2		
Downwind	AF DW Passive	110.0	24	11.59	15	AF	Receive and shred waste in Reception building.	Source separated food waste.	0*	n/a	*Presumptive count per plate
Downwind	MB DW Passive	110.0	9	12.17	15	MB			0*	n/a	
Downwind	GN DW Passive	110.0	9	12.34	15	GN			0*	n/a	

Distances and bearings given in the above table refer to distance/bearing from the Anaerobic Digester / Biofilter area.

Upwind Quarry Greenwaste Composting Area – 09th October 2018

Up Wind Quarry

Site: Bryn Quarry, Gelliargwellt Farm, Gelligaer
Site Operator: Bryn Compost Ltd
Sampling Date: 09/10/2018
Commissioning Laboratory: Cardiff Met, Western Avenue, Llandaff, Cardiff
Estimated Mass of Material:
Type of Material Processed on site: In-Vessel Mixed Food and Green Waste

Location:	Sampling Reference Number:	Difference from boundary of operational area or tuning / screening operation (m)	Difference in bearing location of samplers from boundary / source and mean direction wind blows to (o)	Sampling time: (hh:mm)	Sampling duration (min)	Microbial type	Site activity	Material processed	Calculated concentration of airborne micro-organisms (cfu m-3)	Arithmetic mean of parallel samples (cfu m-3)	Comments relating to any activities occurring during the sampling period that might affect the concentration of airborne micro-organisms
Upwind Quarry	AF UW 1	60.0	21	10.01	15	AF	Screening windrow	Source separated green waste	2	1	
Upwind Quarry	AF UW 2	60.0	21	10.01	15	AF			0		
Upwind Quarry	MB UW 1	60.0	24	10.18	15	MB			12	13	
Upwind Quarry	MB UW 2	60.0	24	10.18	15	MB			14		
Upwind Quarry	GN UW 1	60.0	19	10.35	15	GN			2	1	
Upwind Quarry	GN UW 2	60.0	19	10.35	15	GN			0		

Distances and bearings given in the above table refer to distance/bearing from the quarry composting area.

Downwind Quarry Composting Area – 06th April 2018

Downwind Quarry

Site: Bryn Quarry, Gelliargwellt Farm, Gelligaer
Site Operator: Bryn Compost Ltd
Sampling Date: 09/10/2018
Commissioning Laboratory: Cardiff Met, Western Avenue, Llandaff, Cardiff
Estimated Mass of Material:
Type of Material Processed on site: In-Vessel Mixed Food and Green Waste

Location:	Sampling Reference Number:	Difference from boundary of operational area or tuning / screening operation (m)	Difference in bearing location of samplers from boundary / source and mean direction wind blows to (o)	Sampling time: (hh:mm)	Sampling duration (min)	Microbial type	Site activity	Material processed	Calculated concentration of airborne micro-organisms (cfu m-3)	Arithmetic mean of parallel samples (cfu m-3)	Comments relating to any activities occurring during the sampling period that might affect the concentration of airborne micro-organisms
Downwind Quarry	AF DWQ 1	60.0	3	10.09	15	AF	Screening windrow	Source separated green waste	269	264	
Downwind Quarry	AF DWQ 2	60.0	3	10.09	15	AF			259		
Downwind Quarry	MB DWQ 1	60.0	5	10.26	15	MB			170	156	
Downwind Quarry	MB DWQ 2	60.0	5	10.26	15	MB			141		
Downwind Quarry	GN DWQ 1	60.0	3	10.43	15	GN			2	4	
Downwind Quarry	GN DWQ 2	60.0	3	10.43	15	GN			5		
Downwind Quarry	AF DWQ Passive	60.0	3	10.09	15	AF	Screening windrow	Source separated green waste	0*	n/a	*Presumptive count per plate
Downwind Quarry	MB DWQ Passive	60.0	5	10.26	15	MB			0*	n/a	
Downwind Quarry	GN DWQ Passive	60.0	3	10.43	15	GN			0*	n/a	

Distances and bearings given in the above table refer to distance/bearing from the quarry composting area.

Appendix 4 – Location Specific Meteorological Data – 09th October 2019

Site: Bryn Group, Gelliargwellt Farm, Gelligaer	Site Operator: Bryn Compost Ltd
Sampling Date: 09/10/2018	Commissioning Laboratory: Cardiff Met, Western Avenue, Llandaff, Cardiff
Estimated Mass of Material:	Type of Material Processed on site: Post IVC green and food waste

Location:	Sampling Reference Number:	Bearing of samplers from boundary of operational area or turning / screening operation (o from true north)	Mean direction the wind blows **from** during the sampling period (each individual sample) (o from true north)	Mean direction the wind blows **to** during the sampling period (each individual sample) (o from true north)	Difference in bearing between location of samplers from boundary / source and mean direction wind blows to (o)	Mean wind speed during sampling (m s-1)	Arithmetic mean of air temperature (°C)	Arithmetic mean of relative humidity (%)	Prevailing weather conditions (cloud cover in eighths)
UW of AD facility	AF UW 1	262	216	36	226	4.8	14.6	72	2/8
UW of AD facility	AF UW 2	262	216	36	226	4.8	14.6	72	2/8
UW of AD facility	MB UW 1	262	221	41	221	4.1	14.9	72	2/8
UW of AD facility	MB UW 2	262	221	41	221	4.1	14.9	72	2/8
UW of AD facility	GN UW 1	262	222	42	220	3.2	15.5	74	2/8
UW of AD facility	GN UW 2	262	222	42	220	3.2	15.5	74	2/8
DW of AD facility	AF DW 1	50	206	26	24	4.6	14.5	72	2/8
DW of AD facility	AF DW 2	50	206	26	24	4.6	14.5	72	2/8
DW of AD facility	AF DW Passive	50	206	26	24	4.6	14.5	72	2/8
DW of AD facility	MB DW 1	50	221	41	9	4.1	14.9	72	2/8
DW of AD facility	MB DW 2	50	221	41	9	4.1	14.9	72	2/8
DW of AD facility	MB DW Passive	50	221	41	9	4.1	14.9	72	2/8
DW of AD facility	GN DW 1	50	221	41	9	3.6	15.2	73	2/8
DW of AD facility	GN DW 2	50	221	41	9	3.6	15.2	73	2/8
DW of AD facility	GN DW Passive	50	221	41	9	3.6	15.2	73	2/8

All distances and bearings refer to bearings and distances from the Anaerobic Digester / Biofilter composting area.

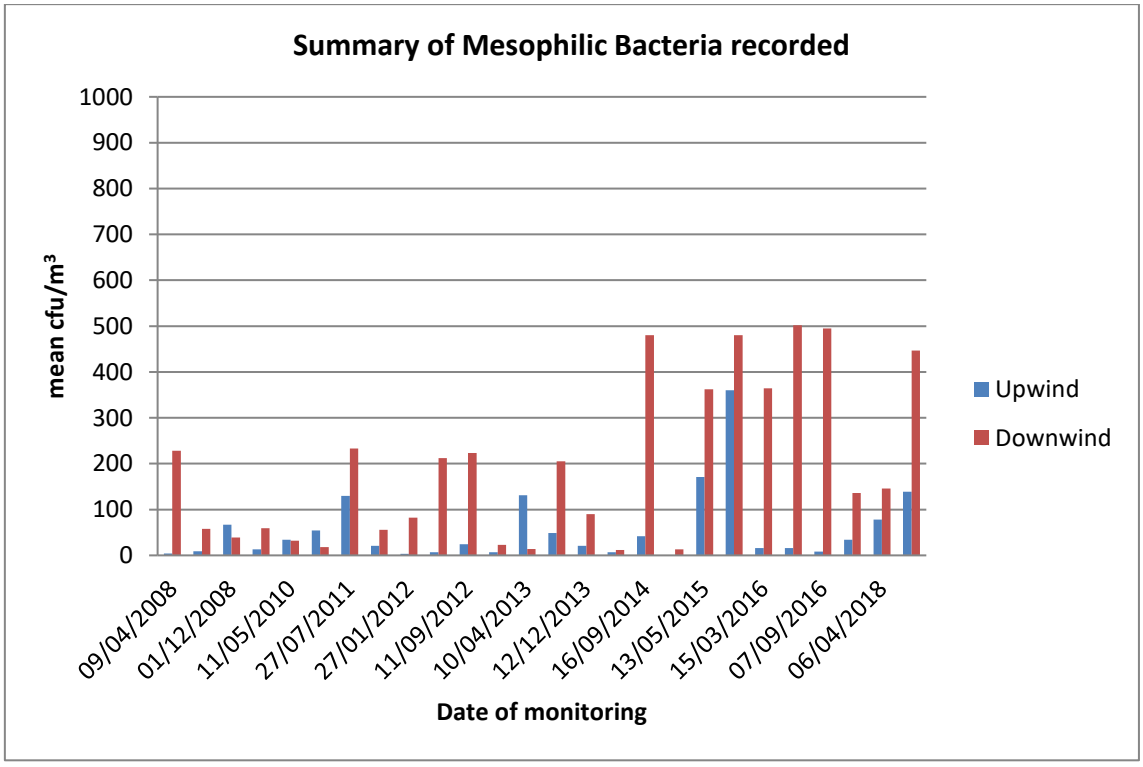
Site: Bryn Group, Gelliargwellt Farm, Gelligaer					Site Operator: Bryn Compost Ltd				
Sampling Date: 09/10/2018					Commissioning Laboratory: Cardiff Met, Western Avenue, Llandaff, Cardiff				
Estimated Mass of Material:					Type of Material Processed on site: Post IVC green and food waste				
Location:	Sampling Reference Number:	Bearing of samplers from boundary of operational area or turning / screening operation (o from true north)	Mean direction the wind blows **from** during the sampling period (each individual sample) (o from true north)	Mean direction the wind blows **to** during the sampling period (each individual sample) (o from true north)	Difference in bearing between location of samplers from boundary / source and mean direction wind blows to (o)	Mean wind speed during sampling (m s-1)	Arithmetic mean of air temperature (°C)	Arithmetic mean of relative humidity (%)	Prevailing weather conditions (cloud cover in eighths)
UW of Quarry	AF UWQ 1	225	201	21	204	2.7	12.3	81	2/8
UW of Quarry	AF UWQ 2	225	201	21	204	2.7	12.3	81	2/8
UW of Quarry	MB UWQ 1	225	204	24	201	3.2	12.5	78	2/8
UW of Quarry	MB UWQ 2	225	204	24	201	3.2	12.5	78	2/8
UW of Quarry	GN UWQ 1	225	199	19	206	3.0	13.1	77	2/8
UW of Quarry	GN UWQ 2	225	199	19	206	3.0	13.1	77	2/8
DW of Quarry	AF DWQ 1	26	203	23	3	3.2	12.4	79	2/8
DW of Quarry	AF DWQ 2	26	203	23	3	3.2	12.4	79	2/8
DW of Quarry	AF DWQ Passive	26	203	23	3	3.2	12.4	79	2/8
DW of Quarry	MB DWQ 1	26	201	21	5	3.0	12.8	78	2/8
DW of Quarry	MB DWQ 2	26	201	21	5	3.0	12.8	78	2/8
DW of Quarry	MB DWQ Passive	26	201	21	5	3.0	12.8	78	2/8
DW of Quarry	GN DWQ 1	26	209	29	3	3.2	13.1	77	2/8
DW of Quarry	GN DWQ 2	26	209	29	3	3.2	13.1	77	2/8
DW of Quarry	GN DWQ Passive	26	209	29	3	3.2	13.1	77	2/8

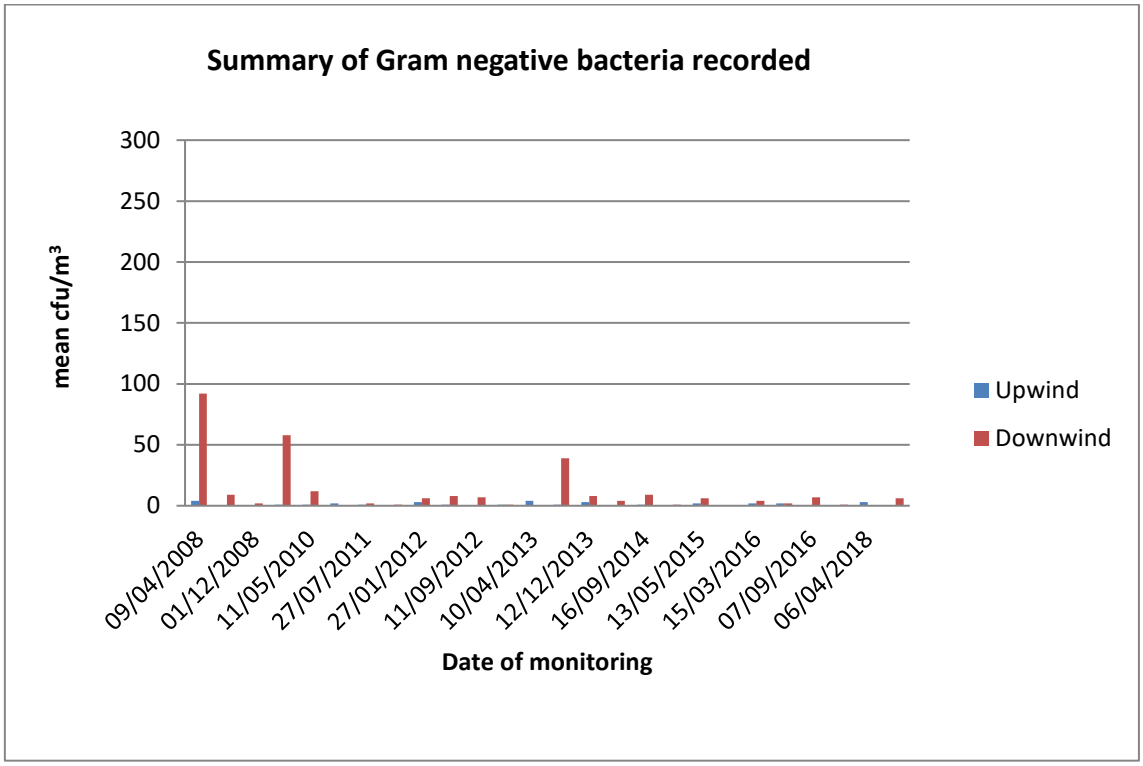
All distances and bearings refer to bearings and distances from the quarry composting area.

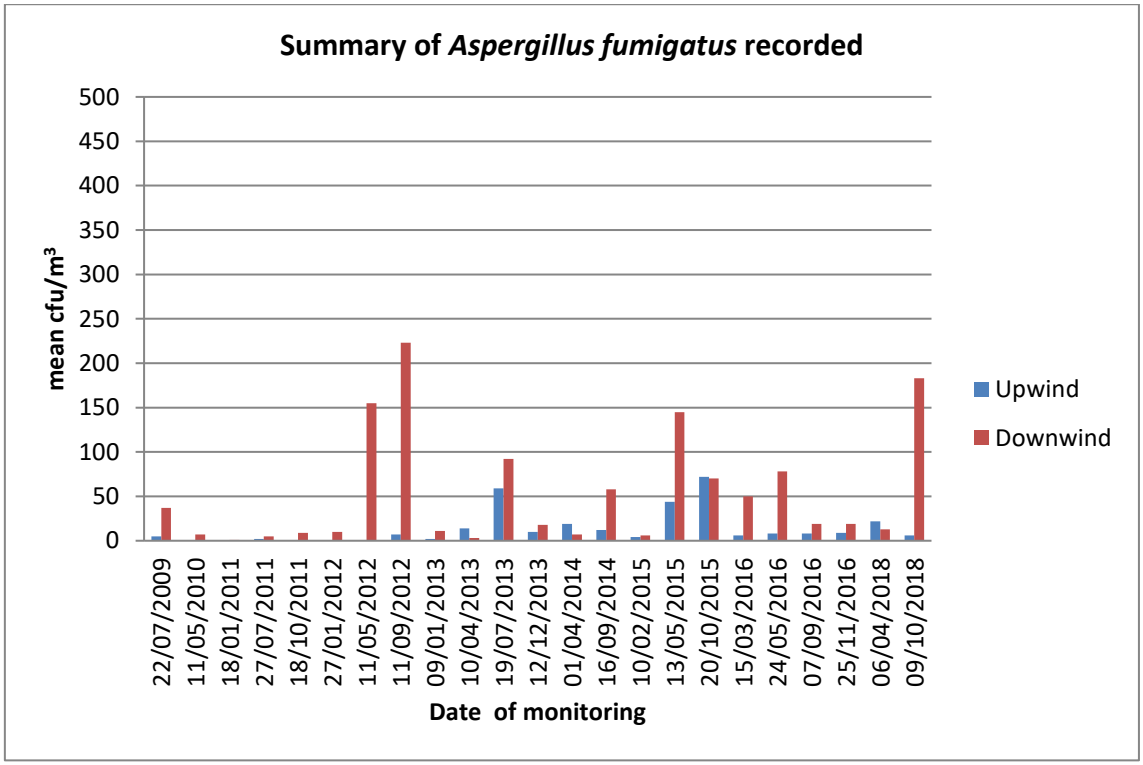
Appendix 5 – Graphical Summary of Previous Monitoring Data

NB: Summary graphs are presented to provide a graphical representation of previous monitoring results. Care should be exercised in interpreting the results, as different monitoring locations, meteorological conditions and work carried out on site during each visit may influence the concentrations observed. Vertical graph axis have been set to the relevant appropriate level, i.e. 1000 cfu/m^3 for mesophilic bacteria, 500 cfu/m^3 for Aspergillus fumigatus and 300 cfu/m^3 for gram negative bacteria.

Data for *Aspergillus fumigatus* has only been recorded since July 2009 when the required measure of fungal concentrations changed from total fungi concentration to *Aspergillus fumigatus* concentration.




Summary of Gram negative bacteria recorded
mean cfu/m³
300
250
200
150
100
50
0
09/04/2008
01/12/2008
11/05/2010
27/07/2011
27/01/2012
11/09/2012
10/04/2013
12/12/2013
16/09/2014
13/05/2015
15/03/2016
07/09/2016
06/04/2018
Date of monitoring
Upwind
Downwind


Summary of Aspergillus fumigatus recorded
mean cfu/m³
500
450
400
350
300
250
200
150
100
50
0
22/07/2009
11/05/2010
18/01/2011
27/07/2011
18/10/2011
27/01/2012
11/05/2012
11/09/2012
09/01/2013
10/04/2013
19/07/2013
12/12/2013
01/04/2014
16/09/2014
10/02/2015
13/05/2015
20/10/2015
15/03/2016
24/05/2016
07/09/2016
25/11/2016
06/04/2018
09/10/2018
Date of monitoring
Upwind
Downwind

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